International Journal of Industrial Engineering & Technology (IJIET)
ISSN (P): 2249–6874; ISSN (E): 2249–7986
Vol. 12, Issue 1, Jun 2022, 9–14
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# ON THE POSSIBILITY OF MANUFACTURING CERAMIC BRICK FROM SALINE LOESS-LIKE LOAMS WITH THE ADDITIVES FROM INDUSTRIAL WASTE

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***ABSTRACT***

***This article presents the results of experimental and theoretical studies on manufacturing effective ceramic products from saline loess-like loams by introducing into the charge the additives from industrial waste. It was determined that the addition of lead ore beneficiation waste to the composition of the clay mass contributes to an increase in the mechanical strength of ceramic samples, the maximum values of which are reached at a firing temperature of 9500C. The ceramic bricks obtained according to the developed charge composition in terms of physical and mechanical characteristics corresponded to grade 125, and when tested for frost resistance, they withstood 40 cycles of alternate freezing and thawing.***

***KEYWORDS. Ceramic Brick, Saline Loess-Like Loams, Charge, Additives, Strength, Frost Resistance, Cycle, Lead Ore Beneficiation Waste, Phase Composition & Capillary Suction***

**Received**: Apr 07, 2022; **Accepted**: Apr 27, 2022; **Published**: May 14, 2022; **Paper Id.**: IJIETJUN20222

Original Article

## INTRODUCTION

It is known that most deposits of clay raw materials used for the manufacture of ceramic bricks contain water-soluble salts, which worsen the color of the front surfaces after firing. During the production process, water-soluble salts dissolve in water and migrate to the surface of the products during their drying; they are fixed during the firing process in the form of whitish or yellowish spots of different intensities [1–3].

To eliminate plaque that forms on the facial surfaces of products, methods were developed that involve the introduction of additives for volume binding of salts during molding, for example, barium compounds [4] or high-alumina cement [5], as well as additives that bind water-soluble salts during firing: vibro-ground quartz sand, tripoli powder, ammonium salts and others [1]. These methods are relatively expensive since ultrafine grinding of additives and the complex technology for mass homogenization are required.

An effective way to eliminate salt efflorescence is to apply protective coatings on freshly molded products [6], which prevent moisture evaporation from their face surfaces in the process of drying, and consequently, the appearance of salt efflorescence. A 4% aqueous solution of Na–CMC, is often used, applied to the surface of a freshly molded bar [7]. The disadvantage of this technique is its low efficiency, since such a solution helps to eliminate whitish spots on the treated face surface of fired products made only from clay raw materials with a low content of water-soluble salts. With an increase in the content of water-soluble salts, the color of the face surface treated with this solution becomes whitish.

In [8], a solution is proposed, consisting of a mixture of boric acid and soda ash, which, when applied to the face surface of a freshly molded product, crystallizes upon drying. Crystals clog the free pores of the facial surfaces, blocking the exit paths for water vapor and capillary-moving water with salts dissolved in it. During laboratory studies, it was found that this solution has a positive effect when clay raw materials with a low and medium content of water-soluble salts (up to 9 meq), mainly $CaSO_4$ and $MgSO_4$ are used. With an increase in the content and the change in water-soluble salts composition, a white coating remains on the treated surface of the fired products.

## MATERIALS AND METHODS

An analysis of the processes in the brick-making plants of the republic indicates a constant shortage and low quality of raw materials, which leads to the search for ways to improve it. The most common way to improve the quality of raw materials is the method of binding soluble sulfate salts of alkali and alkaline earth metals contained in clay with a transfer into an insoluble salt of barium sulfate [9-12].

Along with the widespread method of introducing barium compounds into the feedstock, recently the introduction of additives into the charge has been used; barium compounds react during the firing process with cations of sulfate salts to form low-melting, insoluble newgrowths. Positive results were achieved by introducing low-melting fluxes into the mass, which accelerate the formation of eutectic low-melting melts that bind cations of sulfate salts $Na^+$, $K^+$, $Mg^{2+}$, $Ca^{2+}$ [13-15].

In this study, loess-like loams of Karakalpakstan were chosen as a raw material. To improve the molding properties of the mass and eliminate salt efflorescence on the surface of products, waste coal from the Angren mine and lead ore beneficiation wastes were used as an additive.

The chemical composition of the loess-like loam was characterized by the following data (wt %): $SiO_2$-53,68; $Al_2O_3$-8,10; $Fe_2O_3$-4,08; CaO-11,80; MgO-3,00; $SO_3$-2,50; $Na_2O$-1,53; $K_2O$-2,11 and p.p.p.-12.60. The granulometric composition of the materials used is given in Table 1.

**Table 1: Granulometric Composition of the Materials**

| Raw Material Component | Fraction Size, mm; Fraction Content, % | | | | | |
|---|---|---|---|---|---|---|
| | 1,00-0,063 | 0,063-0,01 | 0,01-0,005 | 0,005-0,001 | 0,001 | ∑ |
| Loess-like loam | 14,16 | 52,16 | 13,88 | 5,52 | 14,28 | 100 |
| Coal waste | 15,41 | 15,11 | 14,00 | 14,68 | 40,80 | 100 |
| Lead ore beneficiation wastes | 28,48 | 47,60 | 7,52 | 9,92 | 6,48 | 100 |

To determine the maximum binding of water-soluble salts, prototypes were prepared, where the amount of tailings from lead ores changed from 3 to 15 wt. %. Technological properties of clay raw materials, such as plasticity, air and firing shrinkage, mechanical strength under bending and compression, were determined in accordance with current industrial and state standards. The amount of water-soluble salts was determined by the method of capillary suction. In order to determine the optimal sintering temperature, the samples were fired at temperatures of 900, 950, and $1000^0$C. The results of physical and mechanical tests of samples are given in Table 2.

**Table 2: Results of Physical and Mechanical Tests of Samples**

| Amount of Additive (waste of Lead Ores), % | Firing Temperature $^0C$ | Water Absorption, % | Volume Weight, kg/cm$^3$ | $\sigma_{сж}$ kg/cm$^3$ | $\sigma_{изг}$ kg/cm$^3$ |
|---|---|---|---|---|---|
| 5 | 900<br>950<br>1000 | 21,28<br>20,79<br>19,36 | 1,563 | 170,4<br>185,6<br>198,6 | 92,64<br>98,32<br>102,24 |
| 10 | 900<br>950<br>1000 | 21,09<br>20,48 | 1,582<br>Overfiring of samples | 177,8<br>197,9 | 94,62<br>103,17 |
| 15 | 900<br>950<br>1000 | 21,0420,06 | 1,599<br>Overfiring of samples | 181,4<br>236,7 | 102,19<br>104,82 |

It was established that with an increase in the content of lead ore beneficiation wastes in the composition of masses, the mechanical strength of the samples increases; the maximum values are reached at a temperature of 950°C, and a further increase in temperature leads to overfiring.

Visual examination of the samples indicates that the surface of the fired samples is uniform without deposits and spots. Capillary suction test confirms that soluble salts in the volume of the samples are completely bound by the components of lead ore beneficiation wastes and do not bloom out to the surface.

## RESULT AND DISCUSSIONS

The analysis of thermogravimetric curves (Fig. 1) also confirms the data reliability of physical and mechanical tests. The composition of the industrial sample (curve 1) is characterized by the presence of endothermic effects at 520 and 850°C. The introduction of 5% and 15% of lead ore beneficiation wastes instead of loess-like loams (curves 2 and 3) leads to a shift of the endothermic effect to the low-temperature region, which is clearly manifested at a waste concentration of 15%. The increase in the intensity of the main endothermic effect at 800$^0$C for the experimental masses is associated with an increase in the decarbonization process, confirmed by a loss increase (to more than 18%).

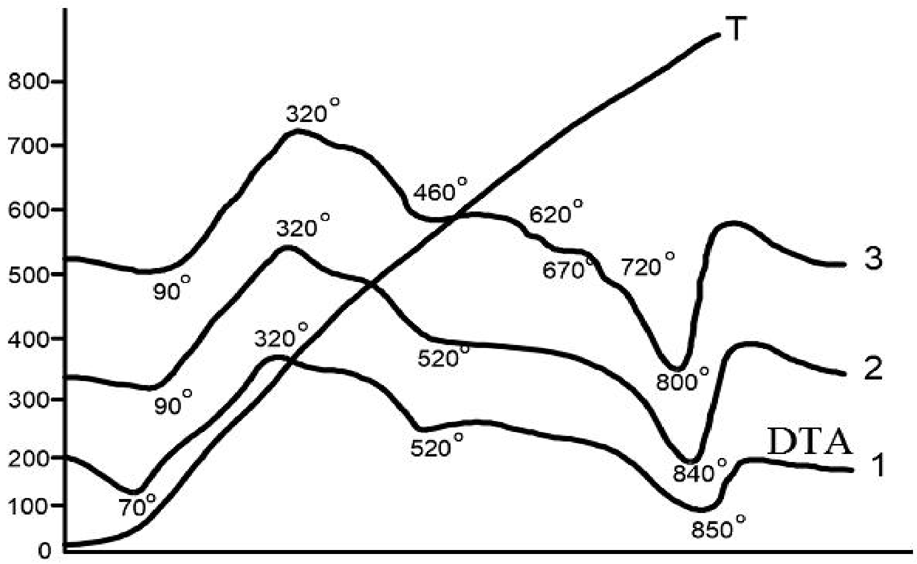


**Figure 1: Derivators of the Samples under Study.**

The beginning of the intensity of the sintering processes in the experimental masses, in contrast to the industrial ones, apparently, is manifested by endothermic effects of low intensity in the region of 620-720$^0$C. Apparently, the main reactions of silicate formation occur in the range of 900-1000$^0$C.

The ICS curves (Figure. 2) of the optimal mass containing 15% of lead ore beneficiation waste after heat treatment at 800, 900 and 1000$^0$C (curves 1, 2 and 3) showed that with an increase in temperature, the absorption bands disappear, which is characteristic of Si-0 deformation vibrations in region of 560-440 cm$^{-1}$. A significant increase in absorption intensity at 640 cm$^{-1}$ characterizes the appearance of Si-0-Si bonds. There are no sharp changes in the intensity of the absorption bands in the region of 700-1300 cm$^{-1}$.

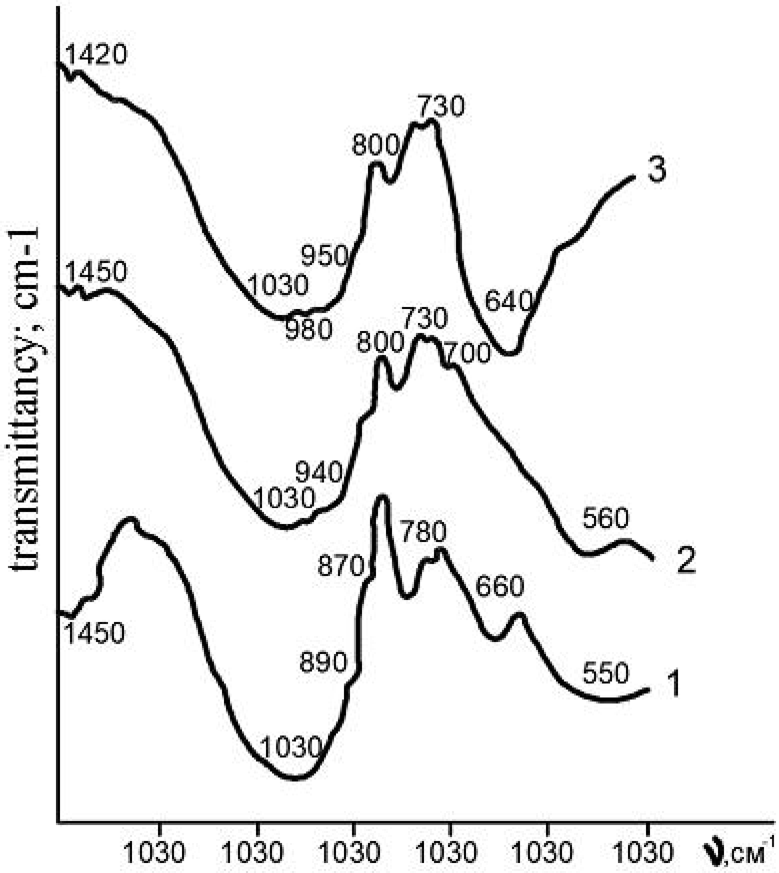


**Figure 2: Infrared Spectra of the Studied Materials.**

Analysis of the phase composition of the raw charge and firing products from the optimal mass at temperatures from 100 to 1000$^0$C shows the presence of minerals: kaolinite (0.714; 0.357; 0.148) nm; chlorite (0.694; 0.350; 0.464) nm; quartz (0.334; 0.181; 0.153) nm; calcite (0.303; 0.104; 0.187) nm; dolomite (0.288; 0.178; 0.219) nm. As a result of the active interaction of CaO with $Al_2O_3$ and $SiO_2$ at a temperature of 900-1000$^0$C with the liquid phase, crystalline phases - anorthite, wollastonite, α-quartz, and others are formed in the microstructure of the ceramic body mass.

To check the reliability of laboratory work, semi-factory technological tests were conducted. Products were molded by the plastic method from the mass containing the optimal amount of lead ore beneficiation waste. The dried products were fired in a ring kiln at 980-1020$^0$C. A high temperature of brick firing was set to decompose volatile soluble salts, which is recommended to eliminate salt efflorescence [14, 15]. Finished bricks withstood 40 cycles of frost resistance

tests and corresponded to grade 125 in terms of physical and mechanical characteristics.

To check the completeness of the binding of soluble salts in the volume of products, tests were conducted for capillary suction. It was found that the introduction of lead ore beneficiation waste into the charge makes it possible to eliminate salt efflorescence on products made of saline loess-like loams and to reduce the firing temperature by 50-70$^0$C compared to serial production.

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